SWITS

The mutual relations of the four gustatory qualities

Psychology

A. B.

1910

UNIV OF ILLINOIS LIBRARY

UNIVERSITY OF ILLINOIS
LIBRARY

Class Book Volume

1910 Sw67

Mr10-20M

Digitized by the Internet Archive
in 2013

http://archive.org/details/mutualrelationso00swit

THE MUTUAL RELATIONS OF THE FOUR GUSTATORY QUALITIES

BY

FRANCIS HOWARD ṠWITS

THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

IN

PSYCHOLOGY

IN THE

COLLEGE OF LITERATURE AND ARTS

OF THE

UNIVERSITY OF ILLINOIS

June, 1910

1910
Sw67

1910
Sw67

UNIVERSITY OF ILLINOIS

MAY 31 1910

190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Francis Howard Swits

ENTITLED The Mutual Relations of the Four Gustatory Qualities

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Arts

in the College of Literature and Arts.

J. W. Baird per S. S. C.

Instructor in Charge

APPROVED: Stephen S. Colvin

HEAD OF DEPARTMENT OF Psychology

168016

TABLE OF CONTENTS.

Statement of Problem	Page 1.
Survey of Work Already Done in Taste	" 2.
Apparatus, Materials and Method	" 8.
Results of the Fatigue Experiments	" 12.
Conclusions	" 23.

THE MUTUAL RELATIONS OF THE FOUR GUSTATORY QUALITIES.

(A) Statement of Problem.

This investigation has to do with the inter-relations of the four taste qualities. It has long since been determined that we are capable of four and only four sensations of taste: - sweet ,- sour,- bitter ,- salt, and that the various flavors which we observe in our foods and ascribe to taste are, in the main, due to the sense of smell. Beyond this fact, little is known of the psychology of taste. Not only is there a meagre amount of experimental data bearing upon the subject, but there is an utter absence of theory as to the intimate nature of the sensory mechanism of taste.

One of the many problems upon which additional light is desirable, is this: What is the relation of these four sensory qualities to one another? In the domain of visual sensation we have become familiar with color compensation, color contrast, and color mixture. We know, for example, that if red and yellow stimuli be mixed, there results a third color quality,- orange. But if we mix a bluish green with our red, the result is a colorless gray. In the one case, we have a composite color resulting from the admixture of simple colors; in the other instance we have a compensation or cancellation of one color stimulus by the mixture with another (complementary) stimulus. We know, too, that if,

after an intensive stimulation of the retina by a red stimulus, we close the eyes, or gaze at a colorless surface, we perceive a blue-green "after image". And indeed if a colorless patch of light be thrown upon a red background, we find that the gray assumes the blue-green tone which is complementary to the background against which it is seen. These mutual relationships of color phenomena have been of a distinct service in enabling us to understand what is the nature of the retinal stimulation, and the question naturally arises: Is it possible to discover analogous relationships obtaining among the gustatory qualities? This is the question which the present investigation attempts to answer. Are phenomena of mixture, of compensation, of cancellation or of contrast characteristic of the sensations of sweet, sour, bitter and salt?

(B) A Survey of the Work Already Done in Taste.

The amount of experimental work already done on taste, is very small. That which has been contributed has proved very valuable in determining certain facts in regard to the nature and cause of the sensation of taste. Probably the first experimental work on taste was undertaken in 1675 when Robert Boyle* investigated the nature of stimulus given to the organs of taste and smell by sapid or odorous substances. In this he puts forward the theory of irritation by particles which penetrate and irritate more or less according to their size and shape. This is

* The bearing of recent discoveries on physics of taste and smell. F. Southerden.
Nature. Vol. 77, 1903, Page 486.

not very valuable as regards scientific investigation, but shows that people were trying in this field to solve some of the problems which are still very unsettled.

In more recent years, namely in 1887, E. H. S. Bailey and E. L. Nichols, of the University of Kansas, performed an experiment and reported in July of that year.* The object of this experiment was to find out what substances or classes of substances are most readily detected by the sense of taste and the relative delicacy of this sense toward these substances. They used five solutions for the production of familiar typical effects upon the organs of the sense; these were (1) quinine for bitter; (2) cane-sugar for sweet; (3) sulphuric acid for sour; (4) sodium bicarbonate for alkaline and (5) saline for common salt. They recognized from the start that the sense of taste is very closely related with the sense of smell. In fact, in some cases we depend upon smell almost entirely to sense some tastes. Their method of testing the delicacy of the sense of taste was to make solutions of known strength of different substances; then by successive dilutions to make from these, several series of weaker solutions, each one being of one-half the strength of that preceding it. The results of their experiments may be summed up as follows.

1. "The sense of taste is much more delicate for bitter substances than for the others included in the list."

2. "Taken in the order of their effect upon the organs of taste, the classes of substances used stand as follows:

* Nature, Vol. 37, pages 557 - 558.

(a) bitter, (b) acids, (c) saline substances, (d) sweets and (e) alkalines."

3. "The ability to detect a dilute bitter is very generally accompanied by an inability to detect a dilute sweet and vice versa."

Roy Tallman reports an experiment* in which the substances which were taken were the ordinary articles of diet. The object of this experiment was to get the relationship of taste and smell in articles of diet. This resulted in showing that there were some substances which could not be tasted at all when the sense of smell was cut off and also that in some substances the sense of smell did not aid at all, at least, no perceptible amount.

In the University of Iowa Studies of Psychology,* Geo. W. Patrick has a general discussion regarding some experiments he performed in taste. The treatment was so general that it does not throw any additional light on this phase of the problem.

Louis Kallenberg*, of the University of Wisconsin, performed an experiment on the action of solutions on the sense of taste. His treatment was more upon the functions of the nerves in sense of taste, that is, the location of the sense of taste, what causes the sensation and what happens when a solution causes a sensation in the mouth.

* "Taste and Smell in Articles of Diet. Psychological Studies. Harlon Gale. July 1900, Page 118.
* "University of Iowa Studies in Psychology, Vol. II. Pages 85 - 128. 1899.
* "The Action of Solutions on Sense of Taste. Bulletin of University of Wisconsin. July 1898.

The specific problem at hand has been attacked by two investigators. In an investigation which consisted essentially in a systematic mixing of pairs of sapid solutions, and describing the tastes of the mixtures, Kiesow* found that compensation or cancellation is not a general or universal phenomena of gustation. Although he tasted every possible combination of his four sapid solutions, he obtained a tasteless resultant or mixture in but a single instance; and even that was obtained only under conditions of exceedingly dilute concentration. He found it to be possible to combine sweet with sour in such proportions that they would give rise to tastelessness, and he obtained a similar negative result from his mixtures of sweet with bitter, sour with salt, sour with bitter and bitter with salt. Only when a dilute, an approximately tasteless solution, of sugar was mixed with an equally weak solution of salt (NaCL) did the phenomenon of compensation appear. When less dilute solutions of these substances were employed his observers recognized the presence of sweet and salt in the mixture. Kiesow's investigation, then throws little light upon our problem.

It is not even permissible to conclude from Kiesow's experiment that phenomena of compensation and contrast do not occur in the domain of gustation, because the well known difference of reaction-time to the different taste qualities renders his method ineffective, and his results valueless. It was long since

* Beitrage zur Psychologie des Geschmacksinnes. Philosophical Studien X. 1894, 523 - 561.

established that if a mixture of the four taste substances be presented to an observer for identification, he will first perceive the taste of salt in the mixture. Soon afterwards he recognizes the presence of sweet; while the identification of sour is slower, and of bitter very much slower than any of the other qualities. This circumstance has been observed and confirmed by numerous investigators; and indeed we now know the exact reaction-time for each of the four qualities, under controlled conditions: Salt, 485 seconds; sweet, 642 seconds; sour 752 seconds; and bitter, 993 seconds. The non-equality of reaction-time makes it impossible to mix any pair of gustatory stimuli in such fashion that an observer will find the mixture to be tasteless. Kiesow's method, then, is wholly inadequate to a solution of his problem - that of stimulating with mixed substances combining sour, salt, sweet and bitter.

In a second series of experiments, however, Kiesow used a different method and obtained results of a positive character. He now prepared his solutions in moderate concentration and applied drops of two different solutions simultaneously to different regions of the tongue's surface. He also employed subliminal stimuli and stimuli of pure distilled water. He hoped thus to determine whether a relatively intensive stimulus is effective in raising a weak stimulus above the limen, or in endowing a wholly insipid stimulus with any taste quality. His results lead him to answer this question in the affirmative. He found that the contrast relations exists between salt and sweet, and between salt

and sour; it is also present, although in lesser degree, between sweet and sour. Bitter, however, occupies a unique position in our gustatory system; it is wholly unrelated with any other taste quality.

In the course of an investigation upon the stimulation of isolated papillae, Oehrwall* came to the conclusion that no relation of contrast or compensation exists between any one taste quality and any other. He is convinced that the organs which respond to the stimulations of sweet, sour, bitter, and salt are wholly unrelated; they are to be conceived of as belonging to different modalities. In the opinion of Oehrwall, therefore, it is as useless to seek for a relationship of contrast or complementariness between pairs of gustatory qualities as it is to hope to find a similar relationship between sweet and cold, between green and aromatic, or between painful and yellow.

There are various circumstances which have caused students of this problem to suspect that the findings and the inferences of both Kiesow and of Oehrwall are contrary to fact. For instance, it is a familiar experience that an orange tastes intensely sour after having eaten sweets. This, it seems to me, cannot be interpreted in any other way than as resulting from a contrast influence of sweet stimuli upon sour stimuli, and analogous relations among the other gustatory stimuli are clearly observable, although perhaps less pronounced. The method outlined below was

* Studier och Undersokningar ofer Smaksmuet, Upsala - 1889, 87pp.

devised for the further investigation; and during the year 1909-1910 the writer has made an experimental study of the problem under the direction of Professor J. W. Baird.

(C) Apparatus, Materials and Method.

The general plan of procedure was as follows: We endeavored to arrange the work and material so that an observer was not obliged to sit more than a half an hour at a sitting. We first determined for each observer the most dilute solution (limen) which could still be identified as sweet, as sour, as bitter and as salt. Then we applied much more highly concentrated solutions (up to ten times the concentration of the limen), in an endeavor to fatigue the organs of taste. Finally, while the phenomena of fatigue were still present, we sought to determine exactly what is the sensory reaction to each of four sub-liminal solutions, and also to distilled water. That is, we hoped to discover how normally tasteless Substances are tasted, if at all, after intensive stimulation by each of the four sapid solutions.

The laboratory work may be divided into two main parts: (1) preliminary orientation (2) final observation. In the preliminary experiments, we prepared sapid solutions of various degrees of concentration. Care was taken to procure chemically pure substances, and to graduate the concentration with the highest degree of accuracy. For valuable aid in this part of the investigation, we are indebted to Dr. A. T. Lincoln, now at the Rensellaer Polytechnic Institute, of Troy, New York, but formerly Assistant

Professor of Physical Chemistry at the University of Illinois; and to Mr. Paul E. Howe, Assistant in Chemistry at the University of Illinois. A preliminary series of determinations showed that the following solutions (stated in terms of molecular weights) were necessary for the establishment of the limina:

Sweet (crystal Domino sugar) $\frac{m}{200}$, $\frac{m}{225}$, $\frac{m}{250}$, $\frac{m}{275}$, $\frac{m}{300}$,

$\frac{m}{350}$, $\frac{m}{400}$, $\frac{m}{450}$, $\frac{m}{500}$, $\frac{m}{550}$, $\frac{m}{600}$, $\frac{m}{650}$,

Sour (Baker's HCh) $\frac{m}{800}$, $\frac{m}{900}$, $\frac{m}{1000}$, $\frac{m}{1200}$, $\frac{m}{1350}$, $\frac{m}{1500}$,

$\frac{m}{1625}$, $\frac{m}{1750}$, $\frac{m}{1875}$, $\frac{m}{2000}$, $\frac{m}{2250}$, $\frac{m}{2375}$, $\frac{m}{2500}$.

Bitter (Quinine sulphate $C_{20}H_{24}N_2O_3H_2SO_4$) $\frac{m}{50000}$, $\frac{m}{66666}$,

$\frac{m}{100000}$, $\frac{m}{133333}$, $\frac{m}{177777}$, $\frac{m}{222222}$, $\frac{m}{266666}$, $\frac{m}{355555}$, $\frac{m}{444444}$,

$\frac{m}{533333}$, $\frac{m}{700000}$, $\frac{m}{888888}$, $\frac{m}{1066666}$, $\frac{m}{1400000}$, $\frac{m}{1777777}$, $\frac{m}{2133333}$,

$\frac{m}{2800000}$, $\frac{m}{3555555}$, $\frac{m}{4266666}$.

Salt (Kahlbaunis NaCL) $\frac{m}{80}$, $\frac{m}{90}$, $\frac{m}{100}$, $\frac{m}{110}$, $\frac{m}{120}$, $\frac{m}{130}$, $\frac{m}{140}$,

$\frac{m}{150}$, $\frac{m}{160}$, $\frac{m}{170}$, $\frac{m}{180}$.

The distilled water we used was perfectly tasteless. This was procured by a process of double distillation, and this was employed throughout both in making the solutions and for purposes of independent stimulation. It was desirable that the solutions should be presented to the observers at a constant and uniform temperature; and in order that distraction of attention by temperature stimulation should be avoided we arranged to present them all at 35° centigrade. This constant temperature was secured as follows: we procured a large tank of galvanized iron 36.5 cm. in diameter and 37.6 cm. in depth, and had a perforated metal shelf fitted across it at a distance of 7.5 cm. from the top. The tank was supported upon a fire-proof base, and a Bunsen burner was adjusted below it. The tank was filled with water. and the 500 cm. bottles, containing the sapid solutions, were placed upon the metal shelf, being immersed in water to about three quarters of their depth. The temperature of the water was registered by an accurate thermometer which was fitted thru the metal shelf. A screen was put up around the tank in such a way that the observer was unable to see the lables upon the bottles; nor could he see an other part of the operation of the experiment.

The exact procedure of each sitting was as follows: The observer was first given a quantity of luke warm water (distilled) with which he was told to cleanse his mouth. Then after a short wait of a minute or two, the experimenter took 2 c. m. of the solution from one of the bottles by means of a graduated, glass pipette, poured this into a luke warm tumbler (kept warm

by being partly immersed in the water in the tank. Small whiskey glasses were used for this purpose). This solution the observer took into his mouth, moved it gently about for a few seconds, discharged it into a convenient receptacle, and reported his introspections. After a brief rest another stimulation was given. The procedure was followed out in an ascending scale from the least concentrated solution up to the highest concentrated solutions. Each solution was presented three times before the next more highly concentrated solution was given. The observer was asked to report the name of the taste and the degree of confidence of certainty with which he was able to make the identification - a scale of three degrees of confidence being used. Confidence "a" represented a mere guess, "c" indicated a moderately high degree of certainty and "e" was specified in cases where there was "no doubt".

In this manner we first determined the liminal stimuli for sweet, sour, bitter and salt for each of five observers. Messrs. J. W. Baird, K. M. Dallenbach, E. O. Finkenbinder, P. H. Mc Kee and H. M. Thrasher served as subjects throughout, and we wish to take this opportunity to express our gratitude for their hearty and patient co-operation in a trying series of experiments.

The accompanying table shows our liminal determinations. The degree of concentration of each solution is expressed in terms of a molecular or normal dilution of the solution in question.

Table I.

The gustatory limina for each observer.

Observer	sweet	sour	bitter	salt
(a)	$\frac{m}{600}$	$\frac{m}{1750}$	$\frac{m}{355555}$	$\frac{m}{100}$
(b)	$\frac{m}{550}$	$\frac{m}{1875}$	$\frac{m}{700000}$	$\frac{m}{160}$
(c)	$\frac{m}{550}$	$\frac{m}{1750}$	$\frac{m}{355555}$	$\frac{m}{90}$
(d)	$\frac{m}{550}$	$\frac{m}{1500}$	$\frac{m}{444444}$	$\frac{m}{140}$
(e)	$\frac{m}{600}$	$\frac{m}{1350}$	$\frac{m}{535333}$	$\frac{m}{100}$

In preparing this table we have done away with all those identifications which were reported to be guesses. It seems probable that only those identifications to which a confidence of "c", or over, attached are worthy of being regarded as perceptions of taste; and these alone have been considered in compiling this table.

(D) Results of the Fatigue Experiments.

In these results we have also eliminated from our consideration those judgments which are confessedly mere "guesses". For these experiments we prepared a series of solutions which were two and a half-fold, five-fold and ten-fold more concentrated than the liminal solutions which had been determined earlier in the investigation. We used these strong solutions as stimuli in order to

bring about a condition of fatigue or exhaustion of the sensory apparatus of taste. The observer retained 2 ccm. of the fatiguing solution in his mouth for a period of ten seconds, washing it about gently in order that the papillae in all parts of the mouth cavity might be stimulated by contact with it. Then this strong solution was discharged; and after a wait of ten seconds, an equal amount of a subliminal solution, or of pure distilled water, was introduced. The observer was not told what the second liquid was, in order that presupposition and prejudice might be eliminated from his identifications. Each observer was instructed simply to - "Describe the sensation obtained from this second stimulus."

There is no doubt that the phenomena was brought about by the conditions which we have described. Even during the ten seconds of primary stimulation the observers frequently reported that the intensity of the gustatory sensation, obtained from the strong stimulus, gradually diminished in intensity and in numerous instances the characteristic quality of the sensation had entirely disappeared before the ten seconds' interval had elapsed. And, also, it was usually noticed that subsequent stimulations by means of the same strong solution, as the series progressed, either arroused gustatory sensation of slight intensity, or wholly failed to arouse a gustatory sensation at all.

The results of these experiments are set down in tabulated form in Table II. The numerical data denote the number of times (expressed in per cents) that each taste sensation was reported. Thus, with all ellipses supplied, the upper section would

read: "After the gustatatory organ had been fatigued by means of a strong sweet solution (two and a half times stronger than the liminal solution previously determined.) a subliminal solution of acid was identified as sour in 55% of our experiments; and bitter in 13% of our experiments. It follows then that in 32% of our experiments this subliminal acid stimulus remained tasteless. After fatigue with the same sweet stimulus, subliminal bitter appeared sour in 7% of our stimulations, and it appeared bitter in 20% of the cases. Subliminal salt, under identical conditions of fatigue appeared sour in 13%, bitter 7% and salt in 33% of the experiments. After fatigue with this sweet water seemed sour in one-fifth and bitter in one-fifth of the experiments. The tabulated data will become intelligible by filling out the ellipsis in similar fashion throughout.

TABLE II.

AFTER FATIGUING by means of STRONG STIMULUS (see margin)

STRONG STIMULI		Subliminal SWEET was tasted as:	Subliminal SOUR was tasted as:	Subliminal BITTER was tasted as:	Subliminal SALT was tasted as:	WATER was tasted as:
SWEET(x 2.5)	Sour		53	77	13	20
	Bitter		13	20	7	20
	Salt		--	--	33	--
SWEET (x 5)	Sour		60	--	13	--
	Bitter		27	60	7	33
	Salt		--	--	47	--
SWEET(x 10)	Sour		40	--	20	--
	Bitter		20	73	7	33
	Salt		13	13	40	7
AVERAGE SWEET	Sour		51	-2	15	7
	Bitter		20	51	7	29
	Salt		4	4	40	2
SOUR(x 2.5)	Sweet	43		20	40	33
	Bitter	7		7	7	13
	Salt	7		27	7	7
SOUR (x 5)	Sweet	23		27	27	20
	Bitter	23		27	13	7
	Salt	15		13	13	20
Sour (x 10)	Sweet	18		13	40	27
	Bitter	18		13	--	27
	Salt	--		--	--	--
AVERAGE SOUR	Sweet	28		20	36	27
	Bitter	16		16	7	16
	Salt	7		13	7	9

TABLE II.(Continued)

AFTER FATIGUING by means of STRONG STIMULUS (see margin)

STRONG STIMULI		Subliminal SWEET was tasted as:	Subliminal SOUR was tasted as:	Subliminal BITTER was tasted as:	Subliminal SALT was tasted as:	WATER was tasted as:
BITTER(x 2.5)	Sweet	--	27		40	20
	Sour	--	20		13	--
	Salt	33	20		13	7
BITTER (x 5)	Sweet	47	40		40	40
	Sour	--	13		27	7
	Salt	13	20		7	7
BITTER (x 10)	Sweet	40	20		47	40
	Sour	--	40		27	7
	Salt	20	7		27	20
TOTAL BITTER	Sweet	29	29		42	33
	Sour	--	24		22	5
	Salt	22	16		16	11
SALT (x 2.5)	Sweet	--	7	13		20
	Sour	--	20	--		--
	Bitter	60	67	60		40
SALT (x 5)	Sweet	33	13	20		7
	Sour	--	20	13		7
	Bitter	53	33	27		47
SALT (x 10)	Sweet	13	20	20		--
	Sour	7	13	--		7
	Bitter	27	33	33		33
TOTAL SALT	Sweet	15	13	18		9
	Sour	2	18	4		5
	Bitter	47	44	40		40

A close observation of these data reveals several significant characteristics. In the first place it is surprising how and to what a considerable extent contrast phenomena occur so frequently in gustation. The second member of each pair of stimuli was normally and objectively a wholly tasteless solution. It was either a solution so dilute as to be insipid and had been reported to be tasteless in numerous previous experiments where fatigue was not present, or it was pure distilled water, whose tastelessness had also been established over and over again in our preliminary stimulations. However, in no less than 591 instances, or in more than 83% of our stimulations, these tasteless liquids were reported to have a distinct taste. It need scarcely be mentioned that some 'after tastes' or 'subjective tastes' are the product of the fatigued condition of the gustatory organ, and that they are exactly the phenomena we had planned to arouse, and to investigate. It seems probable that an examination of their distribution, and of their relation to the fatigue-stimuli which aroused them may throw light upon the mutual relations of the four gustatory qualities.

A close study of the data shows that the distribution of the taste sensations which we have aroused by successive contrast is neither casual nor fortuitous. For example, in the first section of Table II, we find that the largest percent, in each group, represents the number of identifications of each subliminal stimulus in its own sensory quality. This phenomenon is even more prominent in the second, third and fourth sections of the table. This means that sweet has a certain contrast influence upon all

all three of the other taste qualities, or in other words, sweet tends to raise subliminal stimuli of all the four substances above the limen. This, however, is not true of sour, of bitter or of salt i. e., sour, bitter and salt are not opposed, in the relation of contrast to one another as sweet is opposed to them.

Another interesting and remarkable feature of our results is this: the most intensive contrast influence is not obtained by means of an intensive (fatiguing) stimulus. In many instances, more numerous and more intensive phenomena of contrast were obtained after stimulation with a relatively weak stimulus, one whose magnitude was only two and a half times greater than the liminal stimulus. We believe there is no correspondence to this fact in the domain of visual contrast.

There are some interesting results in the fifth column of our table. This column contains an accurate numerical statement of the influence of each of the four gustatory stimuli upon the subsequent taste of a portion of distilled water which under normal conditions is tasteless. It is here that we must expect to find the contrasting effect of tastes expressed in most unequivocal terms; because in all other parts of our table we are dealing with the simultaneous co-operation of two or more factors, in that the subliminal solution of sapid substances does after all, contain a certain amount of sapid substance.

If, now, we further summerize the data obtained from tasting water after fatiguing the gustatory organ, we find a relationship which can best be recorded graphically. The accompanying sketch shows the four taste qualities arranged at the

four corners of a square. The arrow-points upon the sides and diagonals of the square indicate the directions in which the contrast influence may be supposed to operate, and the numbers adjacent to the arrow-points represent the relative magnitudes of the various contrast influences,- expressed in terms of the percentages of their appearance. It will be observed that these numbers vary between the limits of 40 and 2. The average of all is 16. We indicate in red ink all those which are excess of the average. Although this is a some what arbitrary basis of differentiation between presence of contrast and absence of contrast, yet it will be observed, firstly that the numerical magnitudes clearly fall into two different groups, and secondly that a per cent, so small as 2 or 5 or even 16 may readily fall within the limit of a probable error of our apparatus and method. We believe then that we are doing no violence to the facts when we state that our experiments with water as a second stimulus shows the presence of contrast in four of the possible twelve directions or dimensions of contrast influence among gustatory qualities. Whether or not this statement is justified by our data, it clearly is a fact that the most intensive and prominent cases of contrast influence are those of salt upon bitter, of bitter upon sweet, of sweet upon bitter, and of sour upon sweet.

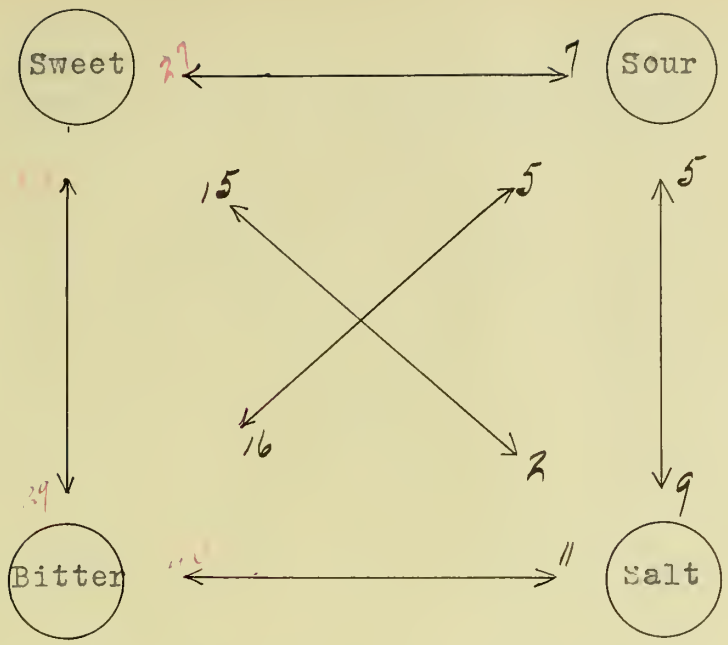


Figure I. Contrast relations demonstrated by the apparent taste of distilled after intensive stimulation by sweet, sour, bitter, salt. The numbers indicate relative frequency of occurance.

A similar schematization of all of our sensory reactions, obtained under all conditions of previous stimulation reveals a relationship whose character is wholly analogous to that just described and pictured.

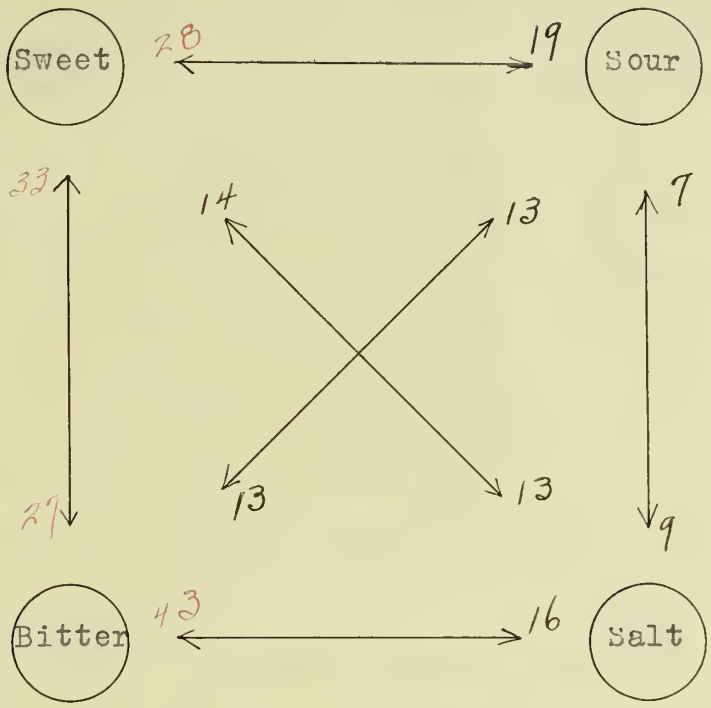
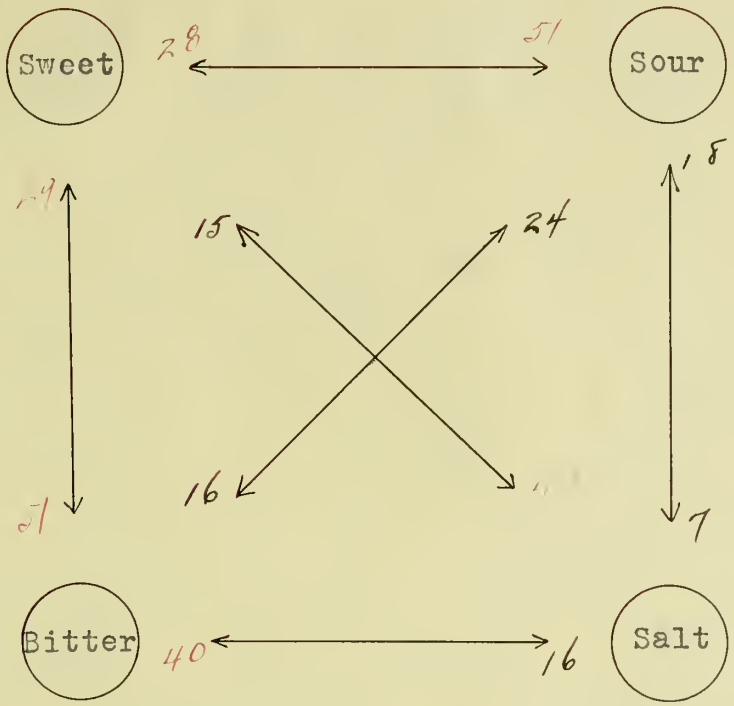


Figure II. Contrast relations - data compiled from all our experiments. The numbers represent the times that the qualities were reported in all of our series, no matter what previous stimulation, or what subsequent (subliminal) stimulation was employed.

It is of course evident that the data from Figure I was prepared seem much better calculated to give us an insight into the essential relationships between the various taste qualities. And the resemblance between Figures I and II is probably to be regarded as nothing more than a remarkable coincidence. However that may be, it surely is very significant that if we turn our attention to that phase of the contrast influence which manifested itself in raising subliminal solutions above the limen, we find, in the main, a corroboration of the relationships which come to light in

Figures I and II but we also note two surprising derivations from coincidence of relationship. The positive contrasts which are manifest in the two figures described above recur in our third figure; but two new contrasts here come to light. It seems hazardous to venture an explanation or interpretation of this discrepancy of result, in the present status of our knowledge of gustatory sensation. It may however be suggested that the contrast influence of sweet upon sour and sweet upon salt is either of such peculiar character or of such small magnitude that it fails to become operative excepting under optional conditions, i.e., when the induced stimulus already contains a certain amount of the substance which is actually recognized as being present in it. On the other hand there is always the possibility that this new and exceptional feature which crops out in the case of certain of our subliminal stimuli is due to the fact of these subliminal stimuli were as a matter of fact liminal. It is true that an earnest endeavor was made to determine exactly what degree of concentration represents a liminal stimulus; but the problem of determining gustatory limina is inherently difficult, and, it may be very uncertain as well. We are convinced that our limina were accurately determined; whether taste sensitively became more refined as our investigation progressed, we cannot say.



(E) Conclusions.

The results of our investigation may be summerized in the following general statements.

(1) Certain characteristic relationships exist between certain of the taste qualities. That both Kiesow and Oehrwall are in error in their statements on this topic has been shown in numerous instances by all of our observers. Contrast in some directions is scarcely less characteristic of gustation as of vision.

(2) Gustatory contrasts do not follow the same simple and regular laws as visual contrasts. (a) The former do not exist in equal degree between all the sensory qualities. Our results indicate that there are four levels of contrast influence among

the gustatory qualities. (b) The most intensive influence is that of salt upon bitter and sweet upon bitter. (c) The influence of bitter upon sweet, of sweet upon sour and of sour upon sweet represents a level of lesser prominence. (d) Much less pronounced is the influence of sweet upon salt, of salt upon sweet, of sour upon bitter and bitter upon sour. (e) The influence of salt upon sour and of sour upon salt is vacillating and under certain conditions non-existant. (f) The influence of contrasting pairs is not always reciprocal, or is not always exercised in both directions. This renders it impossible to represent the mutual relationships of the gustatory qualities in any simple form, analogous to the color-triangle, or the color-square.

(3) Contrasts manifest themselves both in lowering the limen of sensitivity and in endowing pure water with distinct and characteristic tastes which it does not possess in use.